

Glossary

3D videography	An approach to measuring the amount of carbon in forest and other terrestrial ecosystems. A 3D Videography system consists of two cameras, a pulse laser, and a differential GPS sensor mounted to an airplane. It builds a three-dimensional model of a terrestrial ecosystem during a flyover. 3D videography provides detailed information at low cost to enable more proactive ecosystem management.
Above-ground CO ₂ storage	Carbon stored in plants but not roots and soil. In a typical forest, 80% of the total carbon is above ground, whereas on the prairie, only 10% of the total carbon is above ground.
Absorbent, amine	<p>Amines are a class of chemicals that are used to capture CO₂ and/or sulfur dioxide (SO₂) from gaseous process streams. Amines capture CO₂ from a gas by a chemical reaction in which the CO₂ becomes attached to the amine. Heat is required to reverse the reaction and release the captured CO₂.</p> <p>Amines are an ammonia molecule (NH₃) with one or more of the hydrogen atoms replaced with a hydrocarbon compound (an alkyl group, symbolized as R). Primary amines have one hydrogen replaced (RNH₂), secondary two (R₂NH) and tertiary three (R₃N). Amines have different adsorption properties depending on the type and number of alkyl groups added to the nitrogen base.</p>
Absorbent, metal	Solid materials containing sodium or other metals that can chemically absorb and desorb CO ₂ in a regenerable cycle. Leading concepts have adsorbent contacted with the CO ₂ in a fluidized bed. Such systems have potential for low energy use per unit of CO ₂ captured compared to conventional water-based amine absorbents, because they are dry and water does not have to be heated up and cooled down in the absorption/de-sorption cycle.
Acid gas	Chemical species, principally oxides of sulfur (SO _x) and nitrogen (NO _x), contained in flue gas and other process streams that combine with water vapor or water droplets to form acid. They are the precursors to acid rain. Acid gases can corrode pipelines and other process equipment and confound CO ₂ separation technologies, especially at temperatures low enough for water to condense.
Adsorbent, carbon	Amorphous solid carbon materials (as opposed to diamond) physically attract and bind CO ₂ onto their surface and can be used to capture CO ₂ from a gas stream. Amorphous carbon materials produced in different ways have different surface structures and different adsorption properties. Potentially carbon absorbents can capture and release CO ₂ with very little energy required because there is no chemical reaction involved.
Avoided GHG emissions	A measurement of GHG emissions reduction that takes into account the reduced capacity of power plants and other industrial facilities due to the addition of CO ₂ capture systems. For example, if a capture system were installed at a power plant that emitted 100 units of CO ₂ per year, and the capture system captured 90% of the CO ₂ but reduced the power plant's output from 50 units/yr to 40 units/yr, the reduction in terms of avoided emissions would be 10/40 versus 100/50 – a reduction of 87.5%, which is less than 90%. Often avoided emissions calculations assume a method of making up lost capacity. In the above example, if the lost capacity was made up with a power plant without CO ₂ controls (100/50), then the new emissions would be 30 units CO ₂ per year (10 + (10/50)*100), which gives an avoided emissions of 70 units CO ₂ per year which is again less than the 90 units of CO ₂ per year that are captured.

Barrel (bbl)	A measure of volume for petroleum products equivalent to 42 gallons or 0.16 cubic meters.
Bio-accelerated sequestration	A concept of using microbial organisms (microscopic plants or animals) resident with CO ₂ in geologic formations, that sequester the CO ₂ and/or convert it to methane. A key challenge in this area is to identify microbial organisms that can survive the harsh subsurface conditions (i.e., 10,000 psi, 125°C, pH 3-10, and salt concentrations in water of 30% or more).
Biochemistry	The study of chemical compounds and processes occurring in organisms; the chemical characteristics and reactions of a particular living system or biological substance.
Brine	Any solution of water and salt (sodium chloride), usually containing other salts also. Ocean water contains 3% salt. Brines in underground formations can contain 20% salt or more. Brine must be desalinated before it can be used for drinking, and underground formations containing brines are not regarded as drinking water supplies.
British Thermal Unit (BTU)	A measure of energy: the amount of heat required to raise one pound of water one degree Fahrenheit. When one pound of Powder River Basin coal is burned, it produces 8,400 Btu of heat.
Carbon sequestration	The capture and storage of carbon dioxide and other greenhouse gases that would otherwise be emitted to the atmosphere. The greenhouse gases can be captured at the point of emission, or they can be removed from the air. The captured gases can be stored in underground reservoirs, dissolved in deep oceans, converted to rock-like solid materials, or contained in trees, grasses, soils, or algae.
Chemical looping	An advanced system for combustion where metal oxide particles transport oxygen from the air to a fuel. The metal oxide particles are cycled from the combustion reactor to a re-oxidation reactor in a "chemical loop." Chemical looping systems exhaust a stream of high-purity CO ₂ as an inherent part of their operation.
CO ₂ capture	The removal of CO ₂ from a process stream or the atmosphere to produce a highly pure stream of CO ₂ amenable for conversion or storage. CO ₂ capture systems are assessed on the purity of the captured CO ₂ , the percent of total CO ₂ that is captured, and the capital cost and energy use per unit of CO ₂ captured.
CO ₂ enhanced CBM recovery	It is common for coal beds to have methane trapped in pore spaces and adsorbed onto the surface of the coal. In the case of seams that are too deep for economic mining, this coal bed methane (CBM) can be recovered and sold. CBM recovery can be enhanced by injecting CO ₂ into the coal seam, as CO ₂ preferentially adsorbs onto the coal surface and displaces the methane. Nitrogen can also be injected into unmineable coal seams to enhance CBM production.
CO ₂ enhanced oil recovery	The injection of CO ₂ into depleting oil reservoirs to recover additional oil beyond that which would have been recovered by conventional drilling. In the most common CO ₂ enhanced oil recovery (EOR) method, miscible CO ₂ EOR, CO ₂ becomes dissolved in the crude oil and both causes the oil to swell and reduces its viscosity – which drives and enables the oil to slip through the rock formation toward the oil recovery well. At 200,772 bbl of oil per day in 2000, CO ₂ EOR accounted for 5% of total U.S. oil production. It is estimated that 3,000 to 8,000 scf of CO ₂ remains sequestered in the formation for every barrel of enhanced oil recovered.
CO ₂ neutralization sub-surface	Combination of CO ₂ (which is an acid) that has been injected into an underground formation with an alkaline material under conditions such that an acid/base reaction

occurs, forming a benign and stable salt and improving the permanence of carbon sequestration. Certain geologic formations may contain appropriate alkaline materials.

CO ₂ tracer	A readily detectable chemical with flow properties similar to CO ₂ that is added in minute amounts to CO ₂ injected into a geologic reservoir to track CO ₂ migration. Radioactive materials or CO ₂ formed from rare carbon isotopes can be used as tracers.
Coal combustion byproduct (CCB)	Primarily solid ash material consisting of minerals and unburned carbon that is produced as a residual from coal-fired boilers or gasification plants. Category also includes solid material from flue gas desulfurization. Of the 90 million tons of CCB generated annually by U.S. electric utilities, 19 million tons are beneficially used (e.g., fly ash in concrete products, gypsum in wallboard, flue gas desulfurization material in roofing shingles). The remaining 71 million tons are landfilled.
Crosswell Electromagnetic	A technology used to monitor underground fluid characteristics and flows by mapping the resistivity distribution between wells. This technology is complementary to seismic imaging, which is useful in determining geologic strata but does not differentiate between different fluids. Methodologies are currently being developed for utilizing Crosswell EM to track CO ₂ injected into geologic structures.
Cubic Foot (cu ft)	The volume of a cube with edges that are 1 foot in length. A standard cubic foot (scf) of any gas is the amount of the gas contained in a cubic foot at a specific temperature and pressure, generally 60°F and atmospheric pressure (14.7 pounds per square inch).
Depleting oil and gas reservoirs	Reservoirs that have been producing for a while using primary recovery methods and for which the rate of resource production is starting to fall off. Economically viable production from such formations can be extended by methods to enhance production rates including water and CO ₂ floods.
Darcy	A unit of permeability. Permeability is the rate at which a fluid can go through or permeate a solid material. Solids with non-zero permeability are called porous. A porous solid has a permeability of 1 darcy when a pressure of 14.7 pounds per square inch on a sample 1 cm long and 1 cm ² in cross section will force a liquid with a viscosity centipoises through the sample at the rate of 1 cm ³ /sec. (Viscosity is a measure of how resistive a liquid is to flow. Water at 20.2C has a viscosity of 1.0 centipoises.)
Diffraction	Diffraction is the scattering of radiation such as light or x-rays when passed through a material. Various diffraction techniques are used to investigate molecular and crystalline structures. Diffraction techniques are being utilized to investigate CO ₂ hydrates and ocean sequestration. (See Hydrates)
Ecosystem flux	An area of environmental sciences concerned with interconnections and feedbacks among components of the earth system: land, atmosphere and hydrology. Ecosystem flux studies the rate of flow (i.e. flux) of CO ₂ , CH ₄ , water, energy and nutrients and how those fluxes will change in response to changes in climate and increased concentration of CO ₂ in both the atmosphere and surface ocean water. Ecosystem flux also includes the study of how the changes in fluxes will impact regional climates.
Electrical resistance tomography	A technique for producing two- or three-dimensional subsurface images at shallow depths (10-500 feet) by measuring changes in resistivity. These images can be used for the tracking of subsurface fluids such as injected CO ₂ .
Electrochemical pumps	An electrochemical membrane which forces diffusion of CO ₂ or other chemical species across the membrane by the application of an electric gradient - often enhanced by a

pressure differential. Fuel cell technology developed for power generation has been instrumental in the advancement of electrochemical pumps.

Emissions accounting	The measurement, verification, and recording of GHG emissions and GHG emissions reduction activities with the rigor and precision required to incorporate the emissions and emissions reductions into corporate financial statements and legally binding trading mechanisms.
Fate and transport	Term used to describe how a chemical degrades and where it travels when it is released into an ecosystem. Fate and transport analysis is a holistic way of looking at chemicals in the environment and involves a modeling system that indicates not only how a chemical moves through the air, water, soil, and other porous media (transport), but also how the chemical changes in the presence of other chemicals and particles (fate).
Geologic formation	A contiguous underground material which is sufficiently homogeneous to be considered a single unit. Geologic formations with a certain structure and porosity present an opportunity for underground CO ₂ storage, as evidenced by existing formations which have been storing CO ₂ for millions of years. Examples of formations with CO ₂ sequestration potential include depleted oil reservoirs, depleted gas reservoirs, unmineable coal seams, saline formations, and shale formations.
Global warming potential (GWP)	A measure of the magnitude of the heat trapping effect resulting from the addition of 1 kilogram of a gas to the atmosphere relative to that of 1 kilogram of carbon dioxide. GWP is a function of two factors (1) the instantaneous heat-absorbing ability of the gas, and (2) the length of time that emissions of the gas persist in the atmosphere, on average. Gases differ substantially in both heat-trapping ability and atmospheric lifetime. For example, methane is over 100 times more potent of a heat trapper than CO ₂ , but methane's average atmospheric lifetime is only 12 years compared to CO ₂ which persists anywhere between 5 and 200 years. Most GWPs are reported as the average heat trapping effect over 100 years. The 100-year GWP for methane is 23; the 100-year GWP for CO ₂ , by definition, equals 1.
Greenhouse gas (GHG)	A gas which does not absorb radiation of wavelength in the visible light spectrum, but does absorb infrared (heat) radiation. In the atmosphere these gases allow energy from the sun to reach the earth's surface, but limit infrared energy (heat) from escaping. This effect is called radiative forcing. Greenhouse gases absorb 90% of infrared energy radiating from the Earth. Water vapor is the primary GHG, and CO ₂ is the most important GHG emitted to the atmosphere as a result of human activities. CO ₂ accounts for over 80% of the anthropogenic GHG effect. Other GHGs include: methane (CH ₄), ozone (O ₃), CFCs (CFC-11, CFC-12, CFC-113), HFCs (HCFC-22) and nitrous oxide (N ₂ O), CCl ₄ , methyl chloroform, sulfur hexafluoride, trifluoromethyl sulfur pentafluoride, and perfluoroethane. Each gas has a different global warming potential and longevity in the atmosphere.
Greenhouse gas intensity	The emissions of GHGs per unit of economic output. In the year 2001 total U.S. greenhouse gas emissions were 1883 million metric tons of carbon equivalent and the GDP was 9,215 billion dollars (1996 dollars), giving a GHG intensity of 0.204 kg carbon per dollar of GDP. [References: EIA Emissions of Greenhouse Gases in the United States 2001, EIA Annual Energy Outlook 2003]
Horizontal and multilateral wells	Directional drilling is the intentional deviation of a well bore from vertical. Controlled directional drilling makes it possible to reach subsurface areas which would otherwise be inaccessible. It may also be useful for recovery coal bed methane from seams that are long horizontally and thin vertically.

Hydrates	A hydrate is a naturally occurring, ice-like crystalline compound in which a crystal lattice of water molecules enclose a molecule of some other substance. The compounds are very dense and insoluble in water. CO ₂ hydrates are being investigated for use in CO ₂ capture and storage.
MM&V	Measurement, Monitoring, and Verification (MM&V) is defined as the capability to measure the amount of CO ₂ stored at a specific sequestration site, to monitor the site for leaks or other deterioration of storage integrity over time, and to verify that the CO ₂ is stored and unharmed to the host ecosystem.
Membranes	A material that is selectively permeable to one or more chemical species and can therefore be used to separate that species from a gas stream. Selective separation is driven by the partial pressure difference across the membrane surface. Membrane materials are being developed for the separation of CO ₂ from hydrogen, natural gas, and flue gas.
Micro-seismic	Micro-seismic sensors detect sonic-bursts (sounds) generated by sudden small-scale slips/cracking of, or changes in temperature, volume, pressure, or stress in, rock mass formations and geomaterials. These sensors can be used to monitor oil and gas reservoirs for deformation, cracking, and other changes in condition.
Migration of CO ₂	The movement of CO ₂ through a geologic formation driven by density or a pressure differential.
Mineral carbonization	A process in which CO ₂ reacts with magnesium or calcium oxide to form mineral carbonates. The reactions are exothermic, producing 118 and 179 kJ/mole respectively. The mineral carbonates are unreactive solids – highly permanent carbon storage. Challenges include slow reaction rates and the large tonnage of mineral-rich earth that must be mined for each unit of CO ₂ sequestered.
Miscible	The ability of a fluid to dissolve into another, that is mix without forming two phases.
NMR spectroscopy	Nuclear Magnetic Resonance (NMR) is a phenomenon which occurs when a nuclei is placed in a static magnetic field and exposed to a second, oscillating magnetic field. NMR spectroscopy is a method of studying the physical, chemical, and biological properties of matter, including chemical structure, molecular dynamics in solutions, and diffusion coefficients, utilizing this phenomenon.
Ocean fertilization	A concept for ocean sequestration in which infertile waters are seeded with iron or other nutrients to enhance the growth of plankton and consequently the uptake of CO ₂ into the ocean waters.
Ocean injection	A concept for ocean sequestration in which CO ₂ is injected into the mid or deep ocean waters where it dissolves into the ocean water.
Ocean sequestration	The science of storing CO ₂ in ocean waters. Oceans are an important part of the natural carbon cycle because they store, release, and absorb large quantities of CO ₂ to and from the atmosphere. Research in this area is focused on learning more about the ocean carbon cycle, deep ocean ecosystems, and the safety and environmental impacts of CO ₂ storage.
Oxygen combustion	An approach to fossil fuel conversion in which the fuel is combusted in pure oxygen rather than air which is 78% nitrogen and 21% oxygen. Oxygen combustion systems exhaust a stream of highly pure CO ₂ as an inherent part of its operation.

Parasitic steam	A parasitic load refers to steam or electricity use by ancillary equipment that reduces a power plant's net power generation capacity. Water based amine systems for CO ₂ capture from flue gas require a parasitic load up to 30% of plant output.
Post –combustion capture	A system for CO ₂ capture from a fossil fuel conversion where the fuel is combusted in air and then CO ₂ scrubbed, absorbed, or otherwise captured from the flue gas which is primarily CO ₂ and nitrogen.
Pre-combustion capture	A system for CO ₂ capture from a fossil fuel conversion where the fuel is decarbonized via gasification, pyrolysis, or reforming prior to combustion. The synthesis gas from decarbonation is primarily a mixture of CO ₂ and hydrogen. The CO ₂ is captured from the hydrogen before the hydrogen is combusted.
Reservoir	A subsurface, porous, permeable rock body surrounded by impermeable rock and containing oil, gas, or water. Most reservoir rocks consist individually or collectively of limestone, dolomites, or sandstone.
Rio Treaty	Another name for the United Nations Framework Convention on Climate Change (UNFCCC) which was introduced at the 1992 Rio Earth Summit and has since been ratified by 160 nations, including the United States.
Saline formations	Geologic formation of porous rock that is filled with brine.
Soil carbon	<p>Organic and inorganic carbon contained in soil. CO₂ is converted into organic carbon by plants during photosynthesis, and is then deposited in the soil through their roots and in plant residue. Organic carbon is found in the top layer of soil, the A horizon. Inorganic soil carbon are carbonates that form through non-biological interactions. They are a minor amount compared to organic carbon.</p> <p>Soil carbon sequestration occurs through direct and indirect fixation of atmospheric CO₂. Direct soil carbon sequestration occurs by inorganic chemical reactions that convert CO₂ into soil inorganic carbon compounds such as calcium and magnesium carbonates. Direct plant carbon sequestration occurs as plants photosynthesize atmospheric CO₂ into plant biomass. Subsequently, some of this plant biomass is indirectly sequestered as soil organic carbon (SOC) during decomposition processes. Worldwide, SOC in the top 1 meter of soil comprises about 3/4 of the earth's terrestrial carbon; The total carbon sequestration and fossil fuel offset potential of U.S. cropland is estimated 154 million metric tons of carbon per year.</p>
Surface to borehole seismic	Seismic Survey - An exploratory method in which strong low-frequency sound waves are generated on the surface or in the water to find subsurface rock structures that may contain hydrocarbons. The sound waves travel through the layers of the earth's crust, however, at formation boundaries some of the waves are reflected back to the surface where sensitive detectors pick them up. Reflections from shallow formations arrive at the surface sooner than reflections from deep formations, and since the reflections are recorded, a record of the depth and configuration of the various formations can be generated. Interpretation of the record can reveal possible hydrocarbon-bearing formations.
Technology roadmap	A document that identifies all R&D approaches toward a defined endpoint.
Terrestrial ecosystems	Terrestrial ecosystems are defined as all plants, soils, and water bodies that are not a part of the oceans. Annually, terrestrial ecosystems soak up 7 billion tons of CO ₂ . Terrestrial ecosystems are diverse and include tropical, temperate, boreal and plantation forests; woodlands; chaparrals; savannas; grasslands; arctic and alpine tundra; perpetual

ice, desert and semi-desert regions; lakes and streams; wetlands; cultivated and permanent crop areas; as well as cities and other developed areas.

Terrestrial carbon sequestration The absorption and storage of carbon by vegetation and soils in terrestrial ecosystems.

Unmineable coal seams Coal seams which are inaccessible and/or uneconomic to mine due to depth, coal quality, and technological or land use restrictions. (See enhanced coal bed methane)